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Web-based collaborative inquiry learning

K-E. Chang, Y-T. Sung & C-L. Lee
National Taiwan Normal University

Abstract This study proposes a web-based collaborative inquiry learning system. This system uses the World-wide web (WWW) as a source of knowledge exploration, and provides exploratory problems to guide students to think and explore. A concept map is used as a tool of anchoring and representing knowledge during inquiry process. In the process of learning, learners are allowed to exchange the evidence they have collected, their personal opinions, and the concept maps that they have built. In order to effectively integrate the inquiry learning, collaborative learning, and concept map in the system, this study proposes a collaborative inquiry learning model and related learning activities. Two studies were constructed based on the collaborative inquiry learning model to investigate students' learning processes in the collaborative inquiry learning on the web.

Keywords: Collaboration; Concept map; Inquiry learning; Process; Teachers; Undergraduate; World-wide web

Introduction

Modern science education focuses on enabling students to take an active role in learning through their own exploratory processes. Specifically, it tries to help students learn how to organise and construct their own views, reflect on problems, form hypothesis, and seek evidence. Such processes can help students build up their thinking skills and cultivate their problem-solving abilities, thus facilitating the learning of scientific concepts (Tabak *et al.*, 1996).

Inquiry learning is a strategy about student exploration of knowledge. Though researchers have proposed different definitions of inquiry (Suthers, 1996; Looi, 1998; White & Frederiksen, 1998), they generally agree that there are at least four critical steps when conducting inquiry learning: generating hypothesis, collecting data, interpreting evidence, and drawing conclusions. Previous research found that inquiry learning enhances students' learning achievement, especially in the aspects of problem solving skills, ability to explain data, critical thinking, and understanding of concepts in learning science (Chiappetta & Russel, 1982; Saunders & Shepardson, 1987; Haury, 1993).

With the advent of Internet technology, many researchers used computers and the Internet to design a variety of inquiry learning tools. Pryor & Soloway (1997)

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Correspondence: Prof. Kuo-En Chang, Dept. of Information and Computer Education, National Taiwan Normal University, 162, Sec. 1, Ho Ping East Rd., Taipei, Taiwan ROC. Email: kchang@ice.ntnu.edu.tw

developed an inquiry learning software package called ScienceWare. With the assistance of ScienceWare, students can use simulation tools to verify their hypotheses in the process of exploring and establishing their knowledge models. North-western University in the United States developed a learning environment named BGuiILE (Biology Guided Inquiry Learning Environment) in which students learn about biology. This computer-assisted inquiry-learning environment aims not only to make students learn about biology, but also to give them experience in scientific exploration (Tabak *et al*., 1996). Linn (2000) designed a goal-comprehensive and Internet-based inquiry-learning environment for science learning named Knowledge Integration Environment (KIE). The learning environment supports a learner's problem-solving activities with various assistance software tools, combining them with the abundant resources on the Internet as the source of information necessary for problem solving (Linn, 2000; Slotta & Linn, 2000).

Despite its merits, inquiry learning has encountered challenges in implementation. The most emergent problem is the shortage of appropriate software for inquiry learning or teaching in schools. A well designed and testified system for inquiry learning may benefit both teachers' teaching and students' learning. In addition, for inquiry learning to be more effective, it is necessary to strengthen the explorative learning motives of students, to inform them with exactitude what scientific exploration skills are required, and to give them some understanding of the background knowledge (Edelson *et al.*, 1999). Further, without appropriate guides, inquiry learning may turn out to be more of a hurdle for students, except for the brighter few. The problems described above may be overcome with the following solutions:

- Making up for the inadequacy of school facilities with Internet-based on-line exploration software. The Internet is characterised by an abundance of information, speedy update, and ease of access. A web-based system designed according to the procedure of inquiry learning, with easy arrangement of various activities for classroom practice, will empower teachers' instruction a lot.
- Helping students better understand the theme of a learning unit by employing concept mapping. The concept mapping method is widely adopted learning strategy in science education (Novak, 1990). This study uses concept mapping for planning exploration procedures, representing the formed hypotheses, and organising the explored knowledge. Concept maps are helpful for the elaboration of students' declarative knowledge (Roth & Roychoudhury, 1993). Owing to the potential functions of enhancing procedural and declarative knowledge learning, it is hoped that the constructed map may serve as the 'anchor' of the entire learning process and will aid the learner to proceed to meaningful learning.
- Taking advantage of collaborative discussion and information sharing to overcome the difficulties encountered in inquiry learning, lower the hurdles in the way of inquiry learning, and enhance the motives and results of learning. With collaborative learning, the members of a group are encouraged to help each other achieve the shared goals of learning, thereby improving individual learning as well (Slavin, 1986). Researchers were not only interested in the application of collaborative learning in a classroom context, but many were also highly interested in exploring the behaviour and effects of collaborative learning in cyberspace by building environments for collaborative or cooperative learning using computers (Mevarech & Light, 1992; Jehng, 1997; Chang *et al.*, 1999).

This was found to enhance students' ability to think critically, solve problems, and improve interpersonal communication skills (Marjanovic, 1999).

To integrate inquiry learning strategies effectively, collaborative learning strategies and concept mapping knowledge representation into a web-based inquiry learning system, a collaborative inquiry learning model and learning activities is proposed.

Collaborative inquiry learning models

Based on previous studies of inquiry models (Tinnesand & Chan, 1987; Igelsrud & Leonard, 1988; Suthers, 1996; Suthers & Jones, 1997), it seems that the inquiry process should include the following: 1 - familiarising; 2 - hypothesising; 3 - exploring; 4 - explaining; 5 - revising; and 6 - reporting. A four-phase of collaborative inquiry-learning model is proposed and summarised in Table 1. In order for learners to catch the focus in each phase, the learning in each phase is further divided into various learning activities, each corresponding to a learning objective, such as inquiry skills and collaboration skills. Table 1 shows the learning activities in each phase and their corresponding learning objectives for practising inquiry skills or collaboration skills, as well as the results in each phase.

Table 1. Learning activities, objectives, and results in collaborative inquiry learning

Stages	Learning activities	Learning objectives	Results
Phase 1	1. Individual reading of the material 2. Forming hypothesis 3. Constructing individual concept maps	1. Familiarising with the topic 2. Forming hypothesis	1. Individual concept maps
Phase 2	1. Looking for supportive evidence on the web 2. Revising concept maps and editing notepads according to new evidence	1. Exploring 2. Revising	1. Revised individual concept maps 2. Individual notepads
Phase 3	1. Sharing notepads 2. Sharing concept maps 3. Discussion using chat room 4. Revising individual notepad and concept map	1. Data sharing 2. Product sharing 3. Idea sharing 4. Explaining and revising conclusions	1. Individual concept map 2. Individual notepad 3. Chat room dialogue
Phase 4	1. Data sharing in the group 2. Questioning, cooperation, negotiation, compromise 3. Voting to decide the group's core concept map 4. Revising the group concept map	1. Knowledge communication 2. Knowledge negotiation 3. Knowledge consolidation	1. Group concept map 2. Chat room dialogue

Phase 1: anchoring and planning

In the first phase, the learner begins by reading a piece of material that is exploratory in nature and highly worthy of discussion. Then the learner reflects upon the problems raised in the reading material, forming his/her own hypothesis. Next, the learner presents the evidence that supports his/her hypothesis in the form of concept maps. Because learning and organising knowledge with concept maps is known to be effective (Novak, 1990; Chang *et al.*, 2002), it should be feasible to use concept maps to familiarise the learner with the main topics of the reading material. Some researchers think concept mapping is an appropriate planning tool for problem solving (Suthers *et al.*, 1997), so concept mapping is used in the system as a tool for representing knowledge and forming hypotheses.

Three learning activities in Phase 1 depicted in Table 1, with objectives to put learners through the processes of 'familiarising with the topic' and 'forming hypotheses.' At the beginning, learners were provided with reading material by the system. After reading and reflection (learning activity 1), they formed their hypotheses about the reading material. This activity acquainted the learners with the process of ‘familiarising with the topic.’ The processes of familiarising materials and identifying problems are viewed as the anchoring stage. After the anchoring stage, the students proposed tentative hypotheses (learning activity 2) and answered the inquiry problems raised in the reading material. The last learning activity was for learners to present their understanding of the reading material and the evidence relevant in forming their hypothesis in the form of concept maps. The results of this phase will be presented with concept maps built by individuals.

Phase 2: individual inquiry

After the first phase, learners already had a certain degree of understanding of the knowledge of the inquiry problem, and had formed hypotheses. In the second phase, the learners searched resources and looked for the evidence supporting their hypotheses on the web. Additionally, the learners were required to use the notepad function in the system to compile and edit the related information they had found. The notepad they compiled is an outcome of this phase. Finally, the learners revised their original concept maps as constructed in Phase 1 according to what they had learned by reading the information they had found on the web and the views they had found supporting or contradicting their hypotheses.

Phase 3: collaborative inquiry

Collaborative learning emphasises the interactive processes among learners. This study put emphasis on the three parts of collaborative learning: data sharing, product sharing, and idea sharing. In Phase 3 therefore most attention was paid to the sharing of individual notepads, the sharing of individual concept maps, and the discussions between the learners and their peers. Sharing individual notepads to share data; sharing individual concept maps to share products and the discussions and communication between peers are all ways of sharing ideas. When the members failed to reach a consensus, they were allowed to revise their ideas through discussion, questioning, debate and explanation.

Phase 4: concluding group’s results

In addition to individual products, one aim of collaborative learning is for the learning group to make a collective product. Some researchers postulated that the effort to create the group product in collaborative learning is an effective catalyst for discussion and mutual assistance among group members (Slavin, 1996), and therefore an important part of the collaborative learning process. This study asserts that the concept map built by the group can serve as the group product. McManus & Aiken (1995) believed that to create a collective product, voting is one strategy worthwhile trying. Following this idea, the system had each group produce its core concept map through voting. The owner of the winning concept map would then be in charge of revising that concept map so that it became the group concept map. The other members of the group were able to see the map change in real time on the web and could give personal feedback via a chat room. Through discussion, communication, and revision, a group concept map was produced. The objectives of Phase 4, shown in Table 1, were getting learners to engage in knowledge communication, knowledge negotiation and knowledge consolidation (Jehng, 1997).

Study 1

Subjects

The subjects of the experiment are 17 freshmen students from departments unrelated to information science at the National Taiwan Normal University, Taipei. None of them had seen the reading material used in the experiment beforehand. They were divided into six groups, with five groups of three students and one group of two.

Material

The reading material used in this experiment is an article, titled 'The Mystery of The Great Pyramid'. In this article an exploratory question 'Do you think the Great Pyramid was built by humans?' is posed. Two opposing views are presented in the article. One supports the proposition that the Great Pyramid was built by humans, while the other questions that possibility. The reading material provides evidence for both sides of the argument, allowing students to reflect on how to generate their own hypotheses after reading. A search on the web found a wealth of content related to the supportive and dissenting views: nine related Chinese websites contain 3655 webpages supporting either view. Therefore, there was abundant information to provide enough evidence to be quoted in the students' inquiry process.

A 17-item 4-point Likert scale was constructed for students to express their opinions of using web-based inquiry learning. The items aim to understand student responses on the operational difficulty, usefulness and affective acceptance of concept mapping. In each item, 1 indicates 'strongly disagree' and 4 'strongly agree'.

Procedures

This experiment lasted 100 minutes. Considering that the learners were not familiar with the system, the time for system tutorial and explanation must be incorporated into the design of the experiment. The flow of the experiment is shown in Table 2.

Results and discussion

The experiment collected a large corpus of data generated by learners in their inquiry process, including notepads, concept maps, records of discussions and titles of websites visited.

Anchoring and planning phase. In the first phase, the learners were asked to express their understanding of the concept in the reading material using the concept mapping method. They were also asked to propose tentative answers to the problems. Figures 1 and 2 are typical concept maps.

Table 2. Experiment procedures in Study 1

Experiment procedure	Time (minutes)
System tutorial	10
Phase 1: anchoring and planning	20
Phase 2: individual inquiry	20
Phase 3: collaborative inquiry	30
Phase 4: concluding group's results	10
Survey with questionnaire	10

The two concept maps show students have great differences in representing their knowledge. The concept map in Fig. 1 clearly illustrates the view that the Great Pyramid was not built by humans, and the related evidence in the reading material is organised in the map to support this view.

But Student 6a, who authored Fig. 2, does not seem to have produced a concept map related to the reading material to answer the questions. A collection of concepts from the reading is organised in a meaningless manner. It is unclear what his view is.

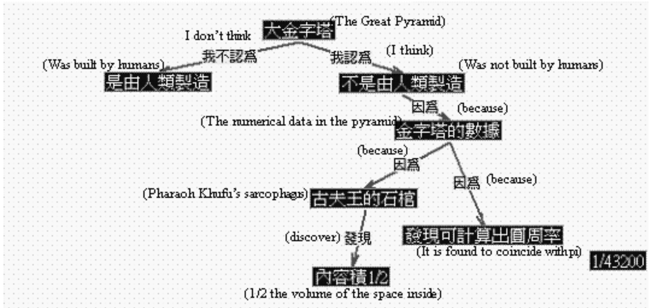

Fig. 1. Concept map produced by Student 4c in Phase 1 (Study 1).

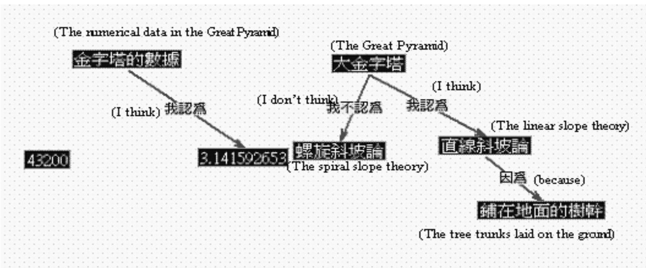

Fig. 2. Concept map produced by Student 6a in Phase 1 (Study 1).

This study tried to use concept mapping as a tool for anchoring concepts in the reading material and for planning hypotheses, but the results indicate that it may produce tremendously different effects when applied on different learners. For some learners, it remained a difficult tool to use for knowledge representation and solution planning. After the interviews it was found that the reasons were largely the lack of knowledge about concept maps, unfamiliarity with the user interface, awkwardness in trying to represent knowledge in concept maps, failure to understand the problems, or doubts about the reading materials.

Individual inquiry phase. In the second phase, the learners went on the web to find evidence that supported their hypothesis. They compiled the evidence they found and record it using the notepad provided by the system. Finally, they revised their original concept maps according to the information in the notepad. Table 3 lists the number of webpages visited by the students in the inquiry processes and the number of webpages quoted in the notepad.

As shown below, the learners did use the web to search for evidence related to their own views. The lowest number of webpages visited by a single student was 17, and the highest, 37.

Some students' notepads were filled with information they culled from the web. The text below shows an example of a notepad, which includes the addresses of the webpages quoted and the abstract of their content written by the student. Students who visited more webpages than others did not necessarily put down the information they found in their notepads.

As shown in Table 3, Student 6b visited 37 webpages without entering any information in the notepad, and Student 5c browsed 35 webpages but recorded only information found in one of them. It seems that when students browse too many webpages, they may become less concentrated in reading and reflecting on content.

The experiment found that browsing websites is indeed a valid form of inquiry activity. This finding is consistent with those of Suthers *et al*. (1997). Chavero *et al*. (1998) used the number of webpages visited by students as one indicator for the amount of inquiry activity taking place. But this study found that the number of webpages visited might not be a proper indicator of judging the level of inquiry activity, because the quantity of webpages browsed has no direct relationship to the quality of mental activity. The study also used the content of notepads as a basis for judging how much the students had read and thought over the assigned material. It was found that those students who had compiled their notepads with more detail and substance actually did better in later phases. Therefore, it is helpful to use the notepad to assist students' exploration. The study also found that a few students have difficulty in organising their findings, so it may be helpful for the achievement of inquiry activities to establish an exploration assistance mechanism. This mechanism may help or oblige students to compile the information they found online, and enter it in the notepad after some reflection and organisation.

Table 3. Web access and citation by the students of Study 1

ID	No. of pages visited	No. of web quotes in the notepad	Initial hypothesis	Final conclusion	Vote for	ID	No. of pages visited	No. of web quotes in the notepad	Initial hypothesis	Final conclusion	Vote for
1a	36	3	Agree	Disagree	1b	4a	17	4	Agree	Agree	4c
1b*	27	2	Disagree	Disagree	1b	4b	21	0	Agree	Agree	4c
1c	30	3	Agree	Agree	1c	4c*	18	1	Disagree	Disagree	4c
2a	19	2	Disagree	Disagree	2b	5a	21	0	Agree	Agree	5b
2b*	17	3	Agree	Agree	2b	5b*	30	3	Disagree	Disagree	5b
2c	30	2	Disagree	Disagree	2b	5c	35	1	Disagree	Disagree	5b
3a	24	5	Agree	Agree	3b	6a	17	1	Agree	Agree	6b
3b*	29	3	Agree	Agree	3c	6b*	37	0	Agree	Agree	6b
3c	17	1	Agree	Agree	3b						

* Students with an asterisk affixed after their ID won the most votes in the group.

http://www.ntut.edu.tw/~s8370021/great.htm
consists of 203 levels of stone blocks
total weight: 6 million tons
2,300,000 stone blocks used in total
http://www.tvbs.com.tw/code/tvbs-g/light-y-file/world-p/y20210w-4.asp
The height of the Pyramid of Pharaoh Khufu times 10 million (98 million miles) happens to be the distance between the Sun and the Earth. Furthermore, the meridian passing through the Pyramid divides the land and oceans into equal halves.

Collaborative inquiry phase The activities in Phase 3 were designed with a view to encouraging learners to have discussions with their partners. It was hoped that they engaged in collaboration on the web and revised their concept maps and the content of their notepads based on what they learnt from the discussions. The discussions in the groups were observed, and it was found that there was much discussion in all the groups. Sharing of ideas and debating individual views can be seen in the discussion records, and the students were found to praise or challenge one another. Such a record is shown below

[1b]: I think it was built by alien beings.
[1c]: I think it was built by humans.
[1b]: Why do you say that?
[1c]: I have no proof.
[1b]: Get out of here.
[1a]: There you go! It was built by the Sun God!
[1c]: There is no evidence of alien presence in the Great Pyramid.

[1b]: No evidence means impossible.
[1b]: You’ve been reading too much mythology.
[1a]: It was mentioned in my notepad!

When Student 1b proposed that aliens built the Great Pyramid, Student 1c immediately countered with his hypothesis that it is a man-made structure. Student 1b then challenges Student 1c for evidence, which Student 1c failed to produce. Student 1a maintained that it was built by a Sun god and invited other group members to look at his notepad for supporting evidence.

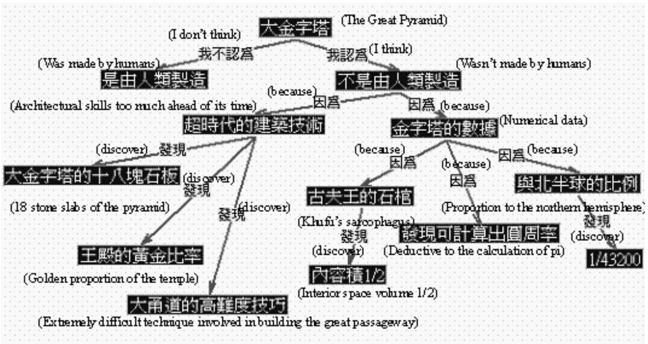

Fig. 3. Concept map produced by Student 4c in Phase 3 (Study 1).

After web inquiry, students incorporated newly found evidence into their original concept maps. For example, Fig. 3 was revised by Student 4c from the original concept map shown in Fig. 1. Some evidence found in web inquiry was incorporated into the original concept map. Newly added concept nodes such as architectural technology ahead of its time, the 18 stone slabs in the Great Pyramid, the golden proportion of the Pharaoh Temple, and the highly difficult techniques in building the great passage way were not included in the original reading material. Those belonged to new evidence that the learner obtained from his web inquiry.

Although most learners attached new evidence to their original concept maps, a few of them revised the concept nodes or links previously established. The information about the 16 students mentioned above was analysed using the McNemar test (Ferguson & Takane, 1989) to examine the changes in the students’ choices after reading the articles and after group-based inquiry learning. The results show that the χ^2-value is 1 ($p > 0.05$), meaning the collaborative exploratory learning approach does not seem to have an observable influence on the change of students’ ideas. In interviews most students said it took too much effort to make changes to previous concept nodes and links, and so avoided doing that. This phenomenon is consistent with what Reader & Hammond (1994) and Fisher (1990) found. Those researchers indicated that most college students were either unable to complete or unwilling to revise their concept maps. It is obvious that feedback for map construction is necessary not only for middle school children (Chang *et al.*, 2001) but also college students.

Jehng (1997) indicated that an effective collaborative learning environment could facilitate the communication, negotiation, and consolidation of knowledge among students. Chang *et al.* (1999) also found that collaborative learning is a way for students to achieve mutual assistance and enhance their learning effects as a result. The system offers a group discussion mechanism, and learners were told to exchange their inquiry data (or notepads), products (or concept maps), and other related ideas. It was also found that group members had actually exchanged ideas from their data and products, thus further clarifying each other's attitudes. In addition to exchange of knowledge, members also had fairly good social interaction. The finding also supports the view of Johnson & Johnson (1989) that the members in a collaborative group will grow 'positively interdependent.

Concluding group outcome phase. The activities in the fourth phase used a voting strategy. Each group selected one individual concept map through voting, and the owner of that concept map was responsible for revising it according to the opinions of the group members. Eventually, the group concept map is thus generated. Table 3 illustrates the voting status of all the students. Students with an asterisk affixed after the ID won the most votes in the group, and were responsible for revising their own concept map after communication and discussion with other group members. The final result is the group concept map. In Table 3, 'Agree' means that the student's hypothesis or conclusion meets the idea 'the Great Pyramid was built by humans', and 'Disagree' means students believe the proposition 'the Great Pyramid was not built by humans'.

There are some interesting results in Table 3. More members of Group 2 were opposed to the idea that the Great Pyramid was built by humans, but their final vote selected a group concept map that supports the idea of men building the Great Pyramid. A similar situation occurred in Group 4. After analysing the dialogue of the groups, it seems that the reason may be that the members wanted to have a more complete concept map from which a group concept map was easily revised. They were willing to choose a better concept map, even if it represented ideas contradicting their own views. Moreover, the hypotheses of members may change after communication and discussion. For example, Table 3 shows that Student 1a displayed dramatic changes in his views, from supporting the idea that the Great Pyramid was built by humans to opposing that idea. The reason for his cognitive change can be found by analysing his notepad.

It appears from the notepad of Student 1a that he changed his original view in the individual inquiry phase, as the content was full of information about the Sun God and numerical coincidence about the Great Pyramid. The student was interviewed to find out what changed his mind, and it seems that the cause was in the process of searching for evidence. He found more evidence showing there are many mysterious and inexplicable numerical and architectural riddles about the Great Pyramid, and so changed his view.

Analysis of questionnaire results. There were 17 items the questionnaire. The objective was to know whether students could easily accept the collaborative inquiry learning model proposed in this paper, if they have any difficulty using the system, their cognitive changes, and other issues they may encounter.

From the questionnaire, the students (94%) thought that learning by 'drawing concept maps' was acceptable, and all of them (100%) agreed that 'drawing concept maps' is an interesting activity. Most students considered the most difficult aspect was lack of time, and the second problem was unfamiliarity with the user interface.

Searching the web for related information was indeed helpful for students to clarify important points in the reading material (88%), and learners agreed that the inquiry process was enjoyable (76%). Most students thought there was a sufficient amount of related information available on the web for exploration (71%).

When the collaborative mechanism was incorporated into the learning process, learners shared information collected on the web and their own ideas with partners.

Through sharing, their ideas become clearer and firmer (75%). Ninety-four percent of the students agreed that sharing information collected on the web and their personal ideas helped them clarify what they really think. Information sharing mentioned in this study included sharing of products (concept maps), data (notepads), and ideas (dialogue and discussion). The students' favourite form of sharing was dialogue and discussion, followed by the content of notepads, and, finally, their concept maps.

As for creating the group concept map, 81% of the students agreed that this activity was helpful for reconciling the differences between group members. But most thought it very difficult to generate a group product (59%), and more than half were not satisfied with their group concept maps (53%). The questionnaire showed that most of the students were willing to change their ideas for the sake of the group product (65%). In summary, students showed positive attitudes towards using a collaborative inquiry learning strategy. All of them agreed that it would be worthwhile to try to use this system in the classroom (100%).

Study 2

Study 1 revealed some problems. The students did not take the initiative to modify their concept maps. In the process of building consensus, they tended to bend their ideas to suit the concept maps that were easier to modify instead of thoroughly clarifying and discussing the problems. As a result they produced concept maps that failed to reflect their true state of knowledge. The reason may be twofold: on the one hand, the learners may not be familiar enough with using concept maps to produce satisfying knowledge representation in limited time; on the other hand, the subject being explored may be not authentic enough to motivate students and therefore, only showed a limited degree of change. To address these problems, the experiment procedure was revised to give students more opportunities to learn about and practice making concept maps, and to enhance their understanding about the importance of matching the form of knowledge representation with information and assumptions in the process of inquiry learning. Second, a subject more directly related to students' lives was chosen to make them more willing to explore in depth, discuss and share their ideas to achieve better results.

Subjects

The subjects of the experiment were 23 in-service teachers, 10 males and 13 females, who were attending the class on computer-assisted instruction. They were divided into seven groups of three or four members each.

Material

The reading material used in Study 2 was an article titled 'The competition of PDAs' (or Personal Digital Assistants). In this article there is an exploratory question 'Who will win out? PalmOS or WinCE?' Like Study 1, two opposing views were presented. One proposed that PalmOS had a good head start and would stay in the lead, while the other stated that WinCE would catch up and win the market in the long run. The reading material provided evidence for both sides of the argument and allowed students to reflect on how to generate their own hypotheses after reading. The web offered a wealth of content related to both supportive and dissenting views: 19 related Chinese websites contained 1420 webpages supporting one view or the other. Therefore, the information was sufficient to provide evidence to support or dispute the arguments. In addition, the majority of the participants were concerned with the application of information technology to instruction and daily life, so the future development of PDAs was a topic closely related to their lives and is worthy of investigation.

Procedures

The procedures used in this study were similar to those of Study 1, except that a two-hour familiarisation stage for concept mapping, collaborative learning and inquiry learning, which was conducted in the class on computer-assisted instruction.

Results and discussion

This study emphasised the changes in students' knowledge of the process of exploration, the changes in their concepts after their collaborative exploration and peer interaction. Table 4 shows the students' original ideas, ultimate ideas, information they had collected, and the consensus they reached as they went through the inquiry activities. It can be seen from Table 4 that, members of the seven groups had diverging original opinions. Of these seven groups, six reached a unanimous consensus after discussion. In other words, about 34% of students with initially dissenting ideas changed their minds through the collaborative inquiry learning.

Table 4. Web access and citation by the students of Study 2

ID	No. of pages visited	No. of web quotes in the notepad	Initial hypothesis	Final conclusion	Vote for	ID	No. of pages visited	No. of web quotes in the notepad	Initial hypothesis	Final conclusion	Vote for
1a	45	7	Palm OS	Win CE	1b	5a	22	4	Palm OS	Palm OS	5b
1b	33	5	Win CE	Win CE	1b	5b	43	11	Palm OS	Palm OS	5b
1c	36	8	Win CE	Win CE	1c	5c	24	8	Win CE	Palm OS	5b
2a	21	5	Win CE	Win CE	2b	6a	33	5	Palm OS	Palm OS	6a
2b	47	4	Win CE	Win CE	2b	6b	27	4	Win CE	Win CE	6b
2c	40	8	Palm OS	Win CE	2b	6c	25	6	Win CE	Win CE	6b
3a	34	6	Palm OS	Win CE	3b	6d	30	9	Palm OS	Win CE	6b
3b	49	9	Win CE	Win CE	3c	7a	43	12	Palm OS	Win CE	7a
3c	37	5	Win CE	Win CE	3b	7b	47	14	Palm OS	Win CE	7a
4a	27	7	Win CE	Win CE	4a	7c	35	10	Win CE	Win CE	7a
4b	31	5	Win CE	Win CE	4a	7d	27	11	Win CE	Win CE	7b
4c	28	7	Palm OS	Win CE	4a						

The information from the 23 students was analysed using the McNemar test (Ferguson & Takane, 1989) to find out the changes in students' choices after they read the article and after the group-based inquiry learning. The result shows that the χ^2-value is 4.5 ($p < 0.05$), meaning that the collaborative inquiry learning indeed has influence on the students' ideas. Compared to Study 1, in which students are mostly reluctant to change their ideas, this study shows a different picture. After improving the students' understanding of the nature of inquiry learning and adopting subjects that are closer to reality and daily life, it was found that students have more discussion and sharing of ideas, which leads to higher likelihood of concept changes.

Conclusions

This paper proposes a web-based collaborative inquiry learning model and learning activities, with the aim of effectively integrating three popular classroom strategies: collaboration, inquiry, and concept mapping.

In Study 1 it was found that when the topic for inquiry is not so closely related to students' lives, they usually lack the motivation to search for more evidence and make clear their concepts. It can also be seen that students are passive in changing their external representation of knowledge when concept mapping is used as a device for knowledge representation under a short period of training. In Study 2, a more authentic topic was adopted and a longer, more intensive training of concept mapping and inquiry were conducted. It was found that student were much more willing to use concept maps to represent their knowledge change, and were more prone to revise their concepts and change their original thoughts. This finding supported the postulation of situated learning (Brown *et al.* 1989; Wenger, 1997) that authentic tasks are more appropriate for inquiry learning.

Though the initial results are encouraging, there remain some limitations worthy of consideration. First, previous studies indicated that concept mapping is not an easy task for students (Reader & Hammond, 1994; Chang *et al*. 2001). This study shows that concept mapping may serve as a device for anchoring ideas and planning hypotheses, yet its difficulty of operation makes students reluctant to change their ideas represented in concept maps. This finding also justified Roth & Roychoudhury's (1993) conclusion that, intensive training is necessary for fully unfolding the epistemic functions of concept mapping for knowledge acquisition.

Second, in the individual inquiry phase, learners enthusiastically explored the web for evidence, and the webpages they visited were related to the topic. However, they did not expend much effort organising the results of their readings and expressing them in their notepads. Some mechanisms of reminding and pushing users to examine the consistency between their hypotheses and collected data may be useful for selecting and organising appropriate material.

Third, in the concluding group's results phase, the voting mechanism can help members generate the group product. However, in the process of negotiation, communication, and consolidation, they often need to sacrifice their individual ideas in order to accommodate students who have produced more complete products. Consensus is a comparatively rare situation. Since the group product is an important indicator of a group's achievement, which can serve as a valid motivator to foster group members' coherence (Slavin, 1996), so it is worthwhile to search for a better method of creating a group's product and preserving the uniqueness of each member's products.

Fourth, most of the teachers in Study 2 said that their teaching can be made more flexible if they have the freedom to use the proper combination of strategies such as collaborative learning, inquiry learning and concept mapping in an on-demand manner, provided that the time factor is under proper control. However, there was no empirical examination or observation of the effects of those teaching strategies when the teachers chose to use them. It is suggested that future studies further explore this aspect to help improve or develop computer software suitable for use in the classroom (Leu *et al*., 1998; Ertmer, 1999).

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Resources and events

IEEE Computer Society - Learning Technology Task Force
http://lttf.ieee.org
This 'home' site provides links to Conferences, Publications and Mailing lists.
The Contact person is Kinshuk at <kinshuk@massey.ac.nz>

12th International World Wide Web Conference (WWW2003) Education track
May 2003, Budapest
see http://www2003.org/

10th ALT Conference: Communities of practice
8-10 September, 2003, Sheffield, UK
see http://www.shef.ac.uk/alt

The 'second wave' of ICT in Education (ICCE 2003)
2-5 December 2003, Hong Kong
see http://www.icce03.org